

The Cryosphere Discuss., referee comment RC2
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Comment on tc-2021-398

Anonymous Referee #2

Referee comment on "Mechanisms and effects of under-ice warming water in Ngoring Lake of Qinghai-Tibet Plateau" by Mengxiao Wang et al., The Cryosphere Discuss.,
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The manuscript (TC-2021-398) by Wang et al. conducted a series of modeling experiments on the formation and development of water temperature rise during the ice-covered seasons in a large freshwater lake of the Qinghai-Tibet Plateau, where lake ice processes and ice-covered lakes were less studied. It is very interesting that weather forcing data in Lake K were used to run the LAKE to simulate the water temperature regime in Lake Ngoring in order to investigate what causes the differences in lake temperature regimes. The paper concluded the intensive solar radiation and absence of snow dominate the development of temperature rising and the temperature rising has significant influence on after-ice-off lake-air heat exchange.

I found this research topics fits well the scope of TC journal. The methods and data analysis are sound. But I have to say the water temperature rising/stratification dynamics is not new since some published observations on QTP lakes and review papers presented this phenomenon, its mechanism is relatively clear. But we still need validation and evaluation of current lake models to reproduce this process in lakes with large solar energy input. However, the motivation and novelty of this work are not clear, maybe largely due to its poor writing and linguistic expression. The manuscript is too long and should be more concise and focused by removing less-related and repeated parts. So I think plenty of extra work is needed to improve the overall quality of this manuscript before it can be considered for publication. Please see my comments below and I hope they would be useful for authors' consideration.

General issues:

The manuscript carried out many sensitivity experiments to varied forcing data and

coefficients. But physically, from the perspective of heat budget and balance of the lake water, only the solar radiation and snow condition can directly change the water temperature, other weather variables have indirect impacts on under-ice water, such as wind, air temperature, and air humidity. I mean these meteor variables directly influence the heat and mass balance of the ice cover.

So one question is, can the LAKE model give the lake ice thickness and temperature evolution? If you look at the modeling results on lake ice evolution under all modelling experiments, it would be easier to understand why the meteor variables and coefficients have differing impacts on water temperature under the ice (like sections 6.2 and 6.3).

Another question is, when the water temperature goes beyond the temperature of maximum density, a *temperature dichotomy* forms (as presented in the GRL paper of the authors, Kirillin et al, 2021, *Ice-covered lakes of Tibetan plateau as solar heat collectors, GRL*). And the regime of the dichotomy layer is of great importance to the water temperature and heat storage, but the inverse temperature gradient/structure above the temperature peak point seems unstable since the temperature crosses the temperature of maximum density. Do you have salinity profiles to look into this regime? Or did the LAKE model reproduce the dichotomy well? How does it change when the solar radiation, optical coefficients of ice and water change? Could you discuss on this? This is important to evaluate the performance of LAKE to reproduce the temperature structure beside value.

Specific comments:

I also recommend the manuscript to be language checked to erase linguistic errors (I found some as below), misunderstandings, and confusions.

- Abstract: although the abstract is very long, I do not clearly get the key points on what this manuscript did, found and concluded. I suggest the authors to make the abstract more concise and more focusing. I suggest the authors follow a conventional flow line of an abstract with background, issues to be targeted, methods used, results and key conclusions.
- Introduction: the introduction looks in a little disorder, so the motivation and novelty of this manuscript looks unclear. It would be better if this part focuses on reviews of typical processes/patterns of under-ice stratification, the differences in QTP lakes (I noticed some results of QTP lakes have been published), and the existing models for lake thermodynamics and their uses for under-ice water. In this way maybe the authors can deliver more clearly your novelty to readers.
- L54: an area larger than 1 km²
- L64-69: Please rephrase these sentences to make it more readable.
- L80-86: I suggest to skip over the introduction on unfrozen lakes.

- L89-102: I don't understand how you define the difference of these two types of under-ice water temperature. I guess the water temperature stratification/structure is very dynamic under the ice cover and undergoes some typical stages as depicted/defined in Kirillin et al (2012), Yang et al (2017, 2021), etc. So maybe it would be better if you introduce the general typical stages of lake temperature stratification through the ice-covered period in boreal, arctic, or temperate lakes, and pointed out the uniqueness or difference of that in highland lakes.

Kirillin, G., Leppäranta, M., Terzhevik, A., et al, (2012). Physics of seasonally ice-covered lakes: a review. Aquatic sciences, 74(4), 659-682.

- L160: 10-m wind speed
- L168-169: The observed site of water temperature should be added to Figure 1. It would be better to provide basic instrumentation information of water temperature here, like apparatus, accuracy and frequency, field setup, and sensor depths.
- L174: to verify the simulated results of what? Surface temperature? As you said, temperature in the MYD11C2 is a 8-day averaged value, so it could lead to uncertainty when you compare your modelling results with MYD11C2. Is there any other product on lake surface temperature that can be used to better evaluate your model results?
- L384-385: the driving data time step is 30 min, why was the model time step set to 15 s?
- Section 2.2.3: How was the ERA-5 Land data used in this manuscript?
- L210-211: Eq (1) seems very complicated, could you please present the physical meaning of each term in the right-hand side?
- Section 3.2: "Validation methods" is not a proper title of this section. This part is actually the method used to evaluate the model accuracy.
- (10): the variable symbols should be consistent to Eq. (1), such as ρ_w , c_w . and i is used to denote ice before and δ is not mentioned in eq (10).
- Section 4: Characteristics Analysis is not an informative title, please be specific.
- L292: how much is the lowest temperature?
- Figure 2: the tick spacing of the color bar seems too large so the spatially and temporally fine changes in the water profiles (including the formation and deepening of convective and diathermal layer) can not be seen clearly as you described in L302-318.
- L307&315: How did you determine the freeze-up and breakup date? From visual observation or remote sensing image (MODIS)?
- Section 4.1.2: Do we have to explain here why the weather conditions are different or similar in the two lakes using complicated geographic or geo-statistic experiences? This is not the key point. I think it would be the best if you present general results on the lake information, ice processes, and the water stratification dynamics through the whole ice season, and more importantly, their differences with that of Ngoring Lake.
- L409-410: "but the whole ice season was shifted to occur about half a month earlier than observed". Can you say a little more on how the LAKE calculate the freeze-up and breakup date, e.g. in the method section? Can you explain why the model gave half-month earlier freeze-up?
- L453: delete "with CTL"
- L468: was reflected..., enters...
- L502: please specify here what the opposite effect is, leading to a decreasing water temperature? In figs. 6b,c,e,f,h, all modeled temperature the upper water layer kept increasing during the ice-covered period.
- L514-515: delete "When the lake is....Polashenski 2012)" since you didn't consider the

snow layer.

- L536-537: I do not understand this sentence. An increment of 0.1 in albedo means an extend of 15-30 d in ice season?
- L558-563: From conventional experiences, with a constant transmitted solar radiation flux, change in light extinction coefficient of water will of course cause changes in water temperature profile, so also you said "*The higher was the extinction coefficient of water, the more heat was absorbed by shallow water and the less heat reached deep layer*", the top water layer should get a higher temperature maximum because the solar energy is used to heat a thinner water layer. If you look at the simulated temperature contours of the whole water column, you may find this regime. But from the point of heat balance, when changing the extinction coefficient of water, the increment in water heat storage doesn't change. I think the authors should elaborate this part.
- Fig 8b: Why were there sharp drops in all scenarios on ~ April 14? In the text, you stated that the ice broke-up on Mar 31-April 1. I guess Fig. 8b showed wrong dates along x-axis.
- Section 6.4: (1) How did you estimate the turbulent sensible and latent heat fluxes? Based on Monin-Obulhov theory? (2) Since you stated that the water structure or continuous warming of upper water before the ice breakup has lasting influences on turbulent heat fluxes on the following 1-2 months, could you please say more on why, through what processes? Right after the breakup, based on heat budget and balance of the lake water, can you estimate quantitatively the contribution of heat storage before the breakup to the turbulent heat change? e.g. comparison between the heat storage and the accumulated heat release to the atmosphere by turbulent sensible and latent exchange.
- L646: "where the air temperature is comparable". I guess not all low-altitude northern lakes have comparable air temperature with QTP lakes. Perhaps some lakes have comparable winter-averaged air temperature, the temporal patterns of air temperatures are different (e.g. even in Fig. 4f).
- L665-666: again, what is the "negative feedback"? Besides, feedback is not an accurate word here, maybe influence, impact, or contribution is better.
- L674-679: this sentence is too long, please rephrase it to be more readable. By the way, what do you mean by "the difference... lasted for 59-67 days..."? do you mean the under-ice temperature profiles have subsequent impacts on turbulent heat exchange at the air-lake interface after the ice breakup?